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Art. XI.—*The Bacchus Marsh Basin, Victoria.*[1]

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(With Plate XVII.)

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I. Introduction.

The Bacchus Marsh area in Victoria has for many years attracted the attention of geologists. Beginning with remarks published by A. R. C. Selwyn in 1861, there has been an almost continuous series of papers and reports regarding this area, no fewer than 84 important references being included in the latest bibliography of Bacchus Marsh Geological literature (1). While most of this deals with the geology of the area, there has been,

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during the past few years, an increasing interest in the complex physiographic features thereabouts.

Because of its economic importance, the Bacchus Marsh "basin" itself has invited special attention, and various opinions have been expressed regarding its mode of origin. None of these suggestions was published, as far as can be discovered, prior to 1907. In 1918, the writer gave some attention to this feature in a paper on the Physiography of the Werribee River Area (2, p. 297).

Although the Bacchus Marsh Basin is so well-known, being on the main road and rail routes from Melbourne to Ballarat, and being visited by practically every geologist whose duty or pleasure brings him to Victoria, a brief account of it may be here given. The Basin is of irregular shape, as shown in the generalised diagram herewith (Figure 1), and is situated in the north-west portion of the Port Phillip Sunkland, just east of the Rowsley Scarp (which bounds the eastern face of the Ballarat Plateau), and to the south of the Greendale and Gisborne scarp faces that mark the beginning of the northern highlands (the Lerderderg and Gisborne Ranges). Five streams meet within the basin, as shown in the figure; the Korkuperrimul, Lerderderg, and Pyrete coming from the north, and the Parwan from the south, while the Werribee crosses the area from west to east. West of the Rowsley Fault (shown by a broken line) the land is over 1000 feet in height, while the plains and hills that surround the basin are from 400 feet upwards, averaging little more than 500 feet. The floor of the Basin is about 200 feet below the level of the country immediately surrounding it.

In the latter part of 1922 the writer decided to develop his notes on this basin, for further publication; and as a preliminary step preparations were made for a relief model, on a scale of two inches to the mile, of the area around the basin, extending to the highlands west of the Rowsley Scarp. The completion of this relief map, from details kindly supplied for that purpose by the Commonwealth Military Authorities, occupied several months, and pressure of other duties subsequently prevented the further preparation of the paper.

In August, 1923, in the Excursion Handbook prepared for the Pan-Pacific Science Congress (1), Dr. H. S. Summers gave a comprehensive account of the geology and physiography of Bacchus Marsh. Special mention was there included of the basin and the flats, and a hypothesis regarding their mode of origin was put forward "with the object of arousing discussion on this difficult problem." The present paper, with the relief map of the area, is submitted as a contribution to this discussion. In addition, reference will be made to some points raised by Dr. Summers regarding the peneplanation and the faulting of the surrounding country, in so far as these matters are pertinent to the subject of this paper. Criticism may be advanced regarding the amount of detail here set out on this one physiographic feature, but the

Fig. 1.—Diagram to show the general heights of the area, the positions of the streams, and the shape of the Basin. R.F. = Rowsley Fault.

wealth of evidence available, and the close bearing of the whole description on the Tertiary palaeogeography of Victoria, are thought to afford justification for such detailed treatment.

II. The Eastward Extension of the Greendale Fault.

Dr. Summers (1, pp. 98-99) points out that the writer, in his account of the Greendale Fault (2) does not deal with its continuance beyond the (later) Rowsley Fault. Careful review of original notes has failed to disclose any justification for this oversight. It is stated, however, in various places in the paper in question (2), that the fault or faults bounding the southern side of the Gisborne Highlands are possibly of the same age; these are in about the same alignment as the Greendale Fault.

The writer's conception is that the Rowsley Fault marks an old line of fracture, so that its influence on the Greendale fault is quite possible. Emphasis was given, in his description of the Greendale fault, to the south-eastern curve as it approached the Lerderderg; it is possible, however, that the Greendale fault bifurcated in the neighbourhood of the Upper Korkuperrimul, and that another branch of the fault continued more directly eastward, to join up with the Coimadai Fault (2, p. 236), and to die out to the eastward. The striking nature of the evidence along Robertson's Creek has perhaps led the writer to over-emphasise the south-easterly curve of the Greendale Fault; this curve brings the Greendale Fault to a tangential junction with the Rowsley Fault, and if the latter is really an ancient fracture line, of an age greater than that of the Greendale Fault, it is conceivable that this portion of the latter might there die out.

Dr. Summers also says (1, p. 99) that the writer "does not suggest any rejuvenation of the Lerderderg until the post-Newer Basaltic movements along the Rowsley Fault." Reference to the paper in question shows, however, that the greater age of the Lerderderg (apart from its pre-uplift existence) is clearly recognised. On page 206, for instance, is the statement: "In the Werribee area we have the Lerderderg, with its long and precipitous gorge, cut over 800 feet deep into very hard folded slates. . . . Meanwhile we have the Werribee, above Bacchus Marsh, cutting a gorge about 700 feet deep in quite similar rocks subsequent to the Newer Basalt period, presumably a much shorter time." The writer agrees with Dr. Summers in believing that uplift along the Greendale-Coimadai-Gisborne fault lines had taken place some time prior to the important happenings that played so great a part in the production of the present Bacchus Marsh topography —namely: The newer volcanic flows and the Rowsley uplift.

As a digression it may be here mentioned that, during the visit of the delegates to the Pan-Pacific Congress in 1923, while viewing the Werribee Gorge from above, Professors W. H. Hobbs and N. M. Fenneman, of U.S.A., expressed the opinion that, judged purely on the work done, they would regard the gorge as a Pleistocene feature. In view of our difficulties in Australia in correlating river work with geological time, this opinion is worthy of record.

III. The Age of the Great Victorian Peneplain.

In a discussion regarding the date of completion of the great Peneplain, the differential uplift of which has so largely determined our Victorian topography (2, pp. 202-212), the writer concluded that peneplanation was complete about the time of the Older Volcanic period, or "not younger than, say, Miocene." This is much earlier than the time suggested by most other Australian workers, excepting Hart (3).

Dr. Summers (1, pp. 97 and 108), suggests that the planation was completed at a still earlier period—the lower Tertiary; he would even put it so far back as "about the beginning of the Tertiary period." His conclusions are based on the age of the Tertiary leaf beds, clays, and lignites of Bacchus Marsh, with which he associates the lignite deposits of Altona Bay, the latter being overlain by marine Tertiaries (Balcombian). Dr. Summers holds that these leaf-beds, etc., are "post-fault"—that is, that they were developed subsequent to the first movements of relative uplift and depression that marked the completion (i.e., the destruction) of the peneplain.

The writer's conclusions (2) were based on the following facts:—

(a) The Great Peneplain of Victoria was one which reached a remarkably complete stage of planation; this must have involved a very long period of still-stand, and as the erosive work in the very latest stages of a peneplaned area become almost infinitely slow, it is conceivable that the peneplain existed, as such, for a very long period indeed. In this case the most easily determined point in time that could be selected to mark the "completion" of the peneplain would be the commencement of those movements of relative elevation and depression that marked the new cycle of highland development.

(b) The opening of the marine invasions of Victorian Kainozoic time are generally accepted nowadays as about middle Tertiary, which suggests that date as the opening of the new cycle of differential crustal movement.

(c) Reasons have been put forward in some detail for associating these earliest post-peneplain crustal movements with the Older Volcanic period, and, while our knowledge of the age and the correlation in time of the rocks known as Older Basalts is admittedly imperfect, it still seems that there is sound reason for associating this period of vulcanicity with the first stages of the destruction of the peneplain.

The latest publications regarding the time relation between the Bacchus Marsh leaf-beds and the pre-Balcombian lignites of Altona Bay do not support the idea of their close association.

The writer therefore approached Mr. Frederick Chapman with a direct question on the matter, and received the following reply, which Mr. Chapman kindly gave permission to use. He says:—"I should certainly regard the Bacchus Marsh leaf-beds as younger than the Altona Bay lignite series. They (the leaf-beds) appear to represent the older part of the terrestrial phase marked out palaeontologically by the Deep Leads flora. I think they are therefore clearly Janjukian, and contemporaneous with the marine phase of the Batesfordian. The Older Basalt *in that area* (Bacchus Marsh) may represent the Lower Miocene; the blocking of the then existent river system may well be conceived as resulting in lakes and swamps, as suggested in Keble's paper on residuals." (4).

There is a vast amount of evidence to the effect that, about middle Tertiary times, there occurred in Victoria conditions that led to widespread and deep accumulations of fluviatile, lacustrine, and estuarine deposits. The writer conceives that at that period the Great Peneplain had reached a stage of something more than advanced maturity—rather of an enfeebled old age—with numerous streams meandering across it, to die in wide, still lagoons and estuaries, or in broad swamps. There is evidence that the period was one of abundant rainfall, and that the relatively higher portions of the peneplain were thickly wooded. It is suggested, also, that the latest stage of the long period of still-stand that produced the Great Peneplain was merged into a very gradual and general movement of depression in south-central and south-eastern Victoria, and that with this depression are associated—

(i.) The clays, leaf-beds, etc., of Bacchus Marsh.
(ii.) The encroachment of the sea at Batesford, etc.
(iii.) The enormous accumulations of lignites and associated sediments (Lal Lal, etc.).
(iv.) The older volcanic period, and the Greendale-Gisborne uplifts.

In future efforts to determine the time of the earliest peneplain-destroying movements of uplift, particular attention might be given to the age of the Older Basalts of central and eastern Victoria, particularly those that cap various portions of the present highland area.

Reviewing the available evidence regarding the progress of the tectonic happenings of the Tertiary period in Eastern Australia, the writer suggests that the sequence was as follows:—Subsequent to the period of uplift that obliterated the Great Cretaceous Sea of Northern Australia, there was a long period of relative still-stand. This still-stand extended through the whole of the lower Tertiary period, and allowed for the completion of a very perfect peneplain, the whole of the eastern[2] half of the continent being reduced by sub-aerial erosion to an almost level surface.

2.—This great peneplain possibly included the whole of the present continent, but the eastern portion is here more particularly considered.

In early Miocene times portions of the peneplain were slowly depressed, particularly in the Bassian area, the Murravian Gulf, and the Great Valley of Victoria. Closely following these depressions, there commenced the epeirogenic movements that were destined to result in the formation of the great bow-shaped horst of the Eastralian Cordillera. This great arc is unsymmetrical about its point of greatest uplift, the Kosciuskan " plexus." The area of maximum upward movement is closely associated with that of maximum downward movement—the Bassian and other related sunklands. The rise of the great Eastralian horst and the formation of Bass Strait commenced in Miocene times. The first important uplift was in the neighbourhood of the Kosciusko plexus, and this movement, slowly extending to the northward and southward, continued with minor oscillations right on through the remainder of the Tertiary Period, culminating in a more intense phase in the early Pleistocene—the Kosciusko Uplift—associated with the Newer Volcanic period.

IV. The Rocks of the Bacchus Marsh Basin.

The general features of the geology of the basin, as far as such factors may have influenced the later physiographic development of the area, are set out in Figure 2. Although this area is one of the most closely mapped and most frequented by geologists in the whole of the State, difficulty was experienced in compiling this diagram, for the reason that previous workers have been most interested in the central and western portion. The detailed geology of the area where the River Werribee leaves the basin, as well as portion of the lower Pyrete Creek area, has never been published, as far as the writer is aware. The map published by Officer and Hogg (5) has provided portion of the geology of the lower Pyrete Creek, and Mr. W. Baragwanath, Director of the Victorian Geological Survey, has kindly procured and supplied some details of the rocks at the place where the Bacchus Marsh Basin narrows down to the steepsided canyon whereby the river leaves the area.

The rocks dealt with here will be classified thus:—

(a) Oldest Rocks.
(b) Tertiary Leaf-beds, etc.
(c) The Newer Basalt Sheet.
(d) The Alluvium of the Flats

(a) *The Oldest Rocks.*—These are exposed in the north-west and north-east. They consist of Ordovician slates and sandstones, glacial sandstones and conglomerates, and older basalts. They are not specially involved in the problem under review, and need not be discussed in detail. The Ordovician slates that are so prominent in the lower Pyrete valley outcrop also in the Djerriwarrh Creek, etc., to the eastward of the lower eastern margin of the area shown in Figure 2. A knowledge of the outcrops and the sub-Newer Basaltic levels of the Ordovician here would

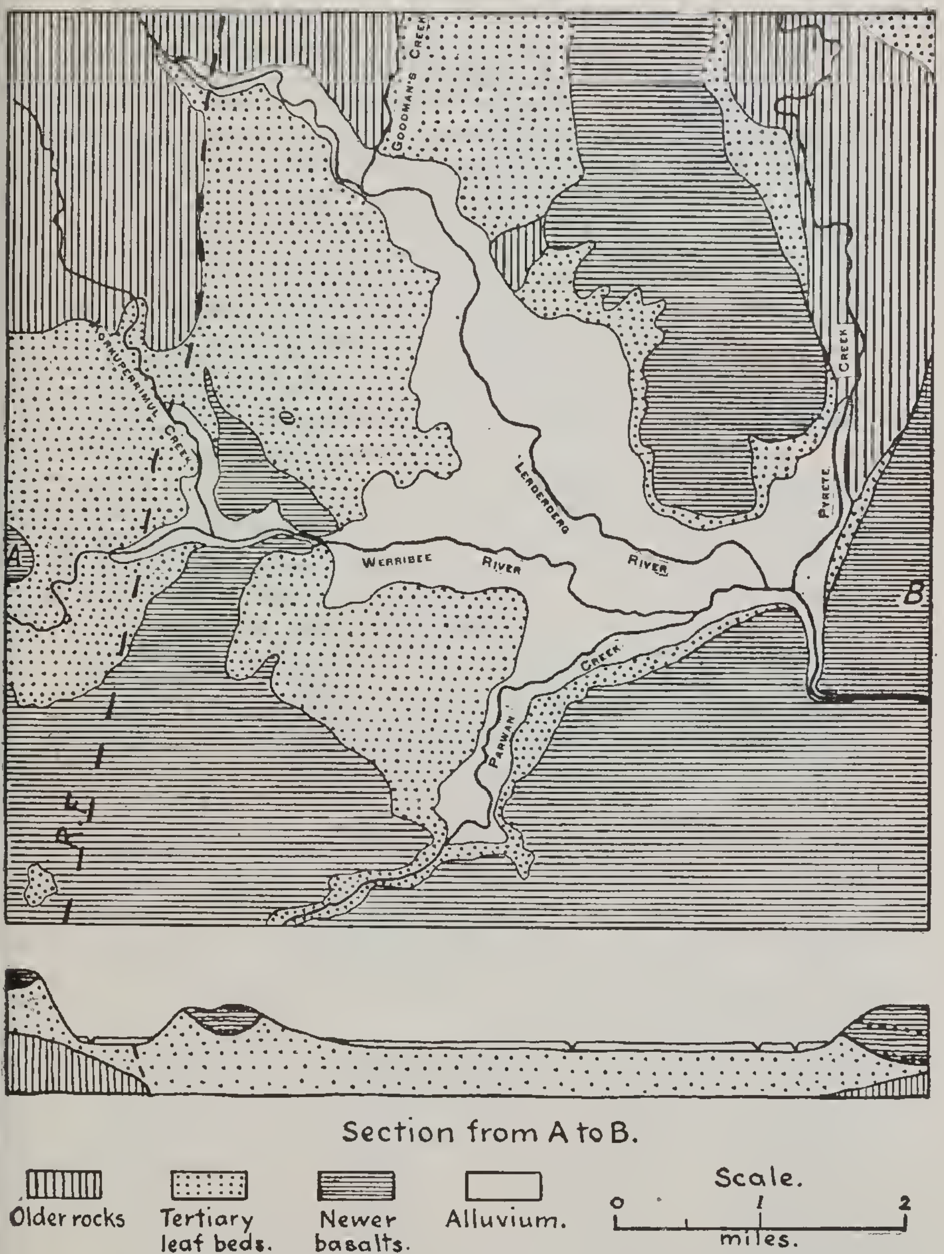

Fig. 2.—Plan and section to show the general geology of the Bacchus Marsh Basin.

possibly have an important bearing on this problem, but such information is not available. Ordovician slates outcrop within the Basin itself in the bed of the Lerderderg River, where it is

crossed by the road from Bacchus Marsh to Coimadai, at Darley. Geological maps usually show an area of Ordovician east of this point, extending up to the base of the Newer Basalt. and of such outline that it is difficult to harmonise same with the general relationships hereabouts. Officer and Hogg (5) give a quite different interpretation, and in an area where so many young geologists ramble, this small point is put forward for consideration. The glacial rocks are of Carbo-permian age, and the older basalts are (?) middle Tertiary. The folded Ordovician slates, etc., are highly resistant to erosion; the glacial materials vary in this respect, but may be classed as easily eroded; the older basalts are almost wholly decomposed, and are thus very readily eroded.

(b) *The Tertiary Leaf-beds.*—These have been abundantly described. In the area west of the Bacchus Marsh flats and east of the Rowsley Fault they are associated with, and have never been definitely separated from, a series of sands, gravels, and boulder beds that, as suggested by Dr. Summers (1), probably represent fault-apron material from both the Greendale and the Rowsley uplifts. The leaf-beds are soft, level-bedded (except where monoclined by the Rowsley Fault movements), and easily eroded, and have been an important factor in the formation of the Basin. They must have originally covered the whole of the area under discussion, and extended well beyond it. They occur throughout the Parwan Valley (2, pp. 278-281). The ease with which these beds are eroded attracted the attention of Wilkinson and Daintree when mapping the area (Quarter-sheet 12 N.E.) in 1868, and those workers suggested that this was due, in part, to the high percentage of soluble salts present in the beds, chiefly sodium chloride and magnesium sulphate.

(c) *The Newer Basalts.*—The newer volcanic sheet covers a considerable portion of the area; it was at one time much more extensive, but has been partly removed by erosion. The important part played by these basalts in the evolution of the present features will be developed later. They form a relatively thin sheet, being rarely more than 400 feet in thickness even where filling old depressions.

Some account should be given here of the geology of the south-eastern part of the area in Figure 2, where the Werribee River leaves the Basin. In the large eight-sheet geological map of Victoria, Ordovician rocks are shown as occurring in the river valley, underlying the basalt. When the writer last had an opportunity of visiting that portion of the area, some eight years ago, he did not realise the critical nature of the geological evidence there, and his notes do no more than indicate, in a general way, that the basalt extends right down to the bottom of the V-shaped valley of the river. In the absence of any detailed map of this part application was made to Mr. W. Baragwanath, Director of the Geological Survey, Victoria, for any information available, and in response thereto, provision was generously made for Mr. A. M. Howitt to pay a visit to the spot. Mr. Howitt's

notes show that two distinct flows of basalt are exposed in the valley walls, the first rock (upper flow) separated from the second rock (lower flow) by sand, gravel and wash. Mr. Howitt visited the south side of the river, adjacent to the Parwan railway station, and mentions that detached blocks of basalt occur in the bed of the Werribee just below the point of junction with the Lerderderg. The northern side was not examined, but the two flows appeared to be exposed there also, as observed from the opposite cliffs. Mr. Howitt's sketch shows neither Ordovician nor Tertiary (leaf-beds) in the narrow gorge of the Werribee. This information, which is very greatly appreciated, has been incorporated in the figures, etc., of the present paper.

The Newer Basalts, as well as any older rocks in this area, have in most parts been covered by wide sheets of fault-apron gravels, sands and silt. In order to simplify matters, these have not been shown in Figure 2.

(d) *The Alluvium of the Flats.*—Economically this alluvium is the most important formation of all; the flats embrace 4500 acres of rich soil. This has been deposited by the work of the five streams:—Lerderderg, Werribee, Korkuperrimul (Lyall's Creek), Parwan, and Pyrete (Coimadai Creek). In a previous description (2, p. 297), it was said that "the complex formations of the surrounding highlands, rich volcanics (older and newer), sandstones, clays, etc., all send their tribute to be blended together for the building up of the wonderfully fertile soil of 'The Marsh.'" In this description the writer failed to note the important fact that the Lerderderg, which has played such a large part in the work accomplished, derives almost the whole of its transported material from the poorest type of rocks in the area—the Ordovician slates and sandstones. The other streams concerned, particularly the Werribee and Korkuperrimul, have much richer and more varied gathering grounds. This has been brought under notice by the following facts.

When preparing the paper on the Werribee River area, the writer received important information concerning relative land values from the late Mr. Robert Dugdale, of Bacchus Marsh. This was incorporated in the paper referred to, with due acknowledgment. As both land and money values have so greatly altered during the intervening ten years, an effort was made to obtain a reliable estimate of present-day values of—

(i.) The alluvial flats of the Basin.
(ii.) The slopes surrounding the Basin.
(iii.) The surrounding upland plains (mostly newer basalt) of Coimadai, Parwan, etc.

This information has been kindly supplied by Mr. Lawrence M. Dugdale, of Staughton Vale, Balliang. Mr. Dugdale's account is so interesting that liberty is taken to reproduce same in full:—

"The best land in the Bacchus Marsh basin does not change hands very often, as it is mostly settled by old families. I might mention that while in business at Bacchus Marsh we

noticed a big difference in the price of the flat land on the Werribee, and that on the Lerderderg River. The Werribee River flats are heavy, black soil, brought from the good lands of Myrniong and Ballan, and I would say an improved farm of these flats to-day would be saleable at from £120 to £150 per acre, according to situation; some small blocks right in the town of small area would bring as much as £180 to £200 per acre. The Lerderderg Flats we did not find quite as good, being more of a sandy loam from the hills of Blackwood and surroundings, and seemed to take more water, and were more subject to dry weather. A good farm on the Lerderderg would bring from £100 to £130 per acre. The bordering slopes are rather hard to value, some being good, others being wind-swept and bare; but I would say that from £9 to £12 per acre is a fair value; in some cases more, where the land is more sheltered. The plains of Coimadai, Rowsley and Parwan vary a good deal; where suitable for hay growing they are worth £12 to £14 per acre, but where they are a little stony and the soil showing more of a red clay, I would say from £8 to £10 was a fair value."

V. The Relief Model of the Area.

Data.—The Bacchus Marsh area has been, most fortunately, included in the sheets prepared and published by the Commonwealth Military Survey. The great importance of these sheets will be increasingly appreciated by geological and physiographic workers as the years go by, and will doubtless give a special stimulus to the carrying out of work within the areas mapped.

While the first sheets published were on a scale of one inch to the mile, with 50 feet vertical intervals, the sheet that includes Bacchus Marsh was published on a smaller scale—namely, half inch to the mile, and with 100 foot intervals. This is called the Ballan-Sunbury-Meredith-Melbourne sheet.

In the latter part of 1922, the writer applied to the Commonwealth military authorities for permission to use their published data in the construction of a relief map, and asked also for a copy of the area around the Bacchus Marsh Basin, on a larger scale, and with the 50 feet contours. The authorities generously granted permission to use their Survey Map for the purposes of this paper, and also supplied a detailed tracing of the area required, on the one-inch scale. The model made is based on this information.

Method of Construction.—Experience of unsuccessful efforts to make relief models without any previous hints or instructions, suggests to the writer the possible value of a brief note regarding the method used in making this model. The map on the one-inch scale was enlarged to a two-inch scale by ordinary methods; this drawing omitted all details not required on the relief map, and was

on tracing cloth. A number of blue prints of this were made, as many as the total number of contour lines involved.

The next step was to decide on the vertical scale—in this case 600 feet to the inch, about 4½ times the horizontal scale. This amount of exaggeration was found most satisfactory, emphasizing the salient features of the relief, without making the model look unnatural. The vertical scale adopted in other cases must of course depend on the amount of relief involved and the area covered.

Having decided on the vertical scale, it was necessary to select a cardboard having the thickness required for one vertical interval (50 feet in this case). The blue prints were mounted on this cardboard, and with a sharp knife one of the cardboard sheets was cut to the shape of each respective contour line. This was a long and tedious work; but became easier with experience. The sheets were then superimposed in the proper order, the bottom one being fixed to a well-seasoned one-inch board, braced against warping. The sheets were fastened one to another with gum and small tacks (shoemaker's "tingles"). This made a permanent model which will stand any amount of usage. The "steps" between the contour lines of the various sheets were then filled in with plastic clay, which hardens on exposure. A mould was made from this model, and the casts turned out as required. For the successful completion of this model the writer is indebted to the generous assistance of Mr. R. M. Craig and Mr. J. A. Tillett, to whom his best thanks are due. It was originally intended to colour the model geologically, but owing to lack of time this proposal had to be abandoned.

VI. Previous Accounts.

(a) *General.*—As far as the writer is aware, no reference to the mode of origin of this Basin occurs in scientific literature before the year 1907. Conjectures were common, and one of these was that the Basin was tectonic in origin. This theory is incorrect, except in so far as faulting in the neighbourhood has had an important influence on the physiographic evolution. Mr. C. C. Brittlebank, the writer understands, long held the opinion that the Basin and Flats were formed by the "downstream cutting" of the Werribee and Lerderderg, working in the soft beds underlying the basalt.

(b) *T. S. Hart,* 1907, (3, pp. 268-9).—Hart briefly describes the formation of the Parwan Valley by the undercutting of the soft Tertiaries below the basalt sheet, with accompanying landslips, etc.; and continues: "A similar explanation can be applied to Bacchus Marsh itself. At the Marsh the valley has been cut through the basalt to the underlying tertiaries. Down stream deepening is less rapid because the hard rocks extend to lower levels and are not yet penetrated. Hence the valley has been greatly widened in the soft rocks."

Commenting on this account, which touches two of the most vital factors in the origin of the Basin, the writer has said (2, p. 299): "It appears that there are important differences in origin between the Parwan Basin and the Bacchus Marsh Basin, although the rocks worked in are closely similar. The Parwan Basin is on the upthrow side of the fault line (Rowsley Fault), with the accompanying rejuvenation of its streams. The Bacchus Marsh Basin lies on the downthrow side of the fault, where aggradational work would be done by the rivers, possibly until such time as the lower Werribee established a channel in the Newer Basalt. The Parwan Basin has been mainly accomplished by the headward erosion of steep tributary valleys. This can hardly have been the case with the Bacchus Marsh Basin."

(c) *C. Fenner,* 1918, (2, pp. 297-300).—In the pages mentioned the writer gave what he then considered was a reasonably full account of the mode of development of the Basin, with suggestions of perplexity as to the manner in which the formation was actually commenced. The causative factors then given were:—

(i.) A bar of hard rock (the basalt filled valley of the ancient Bullengarook River) at the point where the Werribee now leaves the Basin.

(ii.) Soft, easily-eroded rocks underlying the basalt sheet around the eastern and southern portions of the Basin.

(iii.) The fact that five relatively important streams meet together in this area, doing most of the work by "side-swinging."

(d.) *H. S. Summers,* 1923, (1, p. 102).—The hypothesis put forward by Dr. Summers introduces a new factor, and one which provides a means of accounting for the actual *beginning* of the Basin, by mention of the fan delta accumulations of the Lerderderg River below the Greendale fault (or the equivalent eastward continuation of that fault scarp). Dr. Summers would appear to closely associate the Lerderderg fan delta materials with the Tertiary leaf beds, and whether this is accepted or not, his hypothesis throws a fresh light on the physiographic conditions that existed at the time of the newer basalt flows, and that played so great a part in determining the present features.

His remarks, with observations made by the writer in this area since 1918, and discussions of the subject with visiting physiographic workers, have stimulated the production of this attempt to give a detailed explanation of the progressive development of the physiographic features of Bacchus Marsh.

VII. The Origin and Development of the Bacchus Marsh Basin.

(a) *The Chief Causative Factors.*—These are as follow, arranged in a more or less chronological order:—

(i.) The pre-Newer Basaltic topography.
(ii.) The extent and outline of the Newer Basalt flows.
(iii.) The convergence to this centre of five important streams.
(iv.) The ease with which erosion could proceed in the soft Tertiaries underlying the basalt sheet.
(v) The existence of a hard bar of rock at the place that now marks the south-eastern limit of the basin.

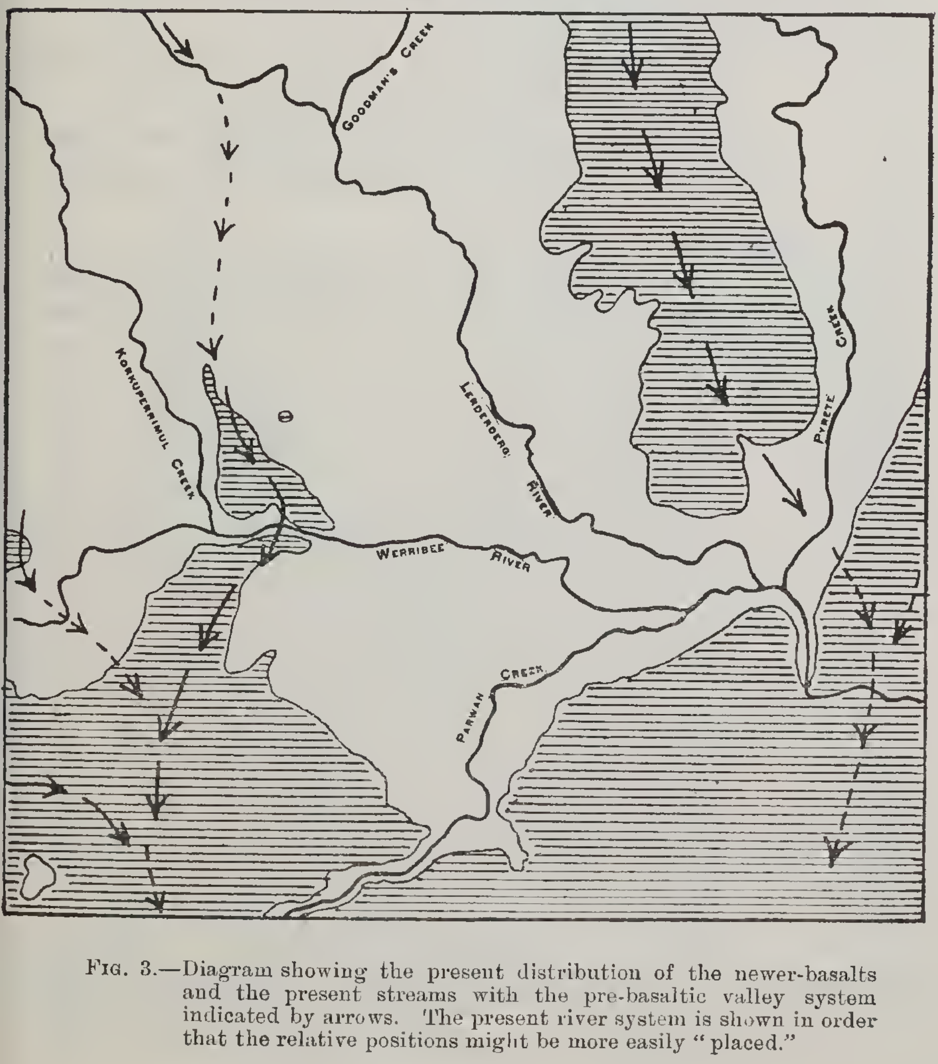

Fig. 3.—Diagram showing the present distribution of the newer-basalts and the present streams with the pre-basaltic valley system indicated by arrows. The present river system is shown in order that the relative positions might be more easily "placed."

(b) *The pre-Newer Basaltic Valleys.*—In the endeavour to arrive at a reconstruction of the pre-newer basaltic topography, the criteria adopted will be those outlined in previous work in this area (2, pp. 289-290). The conclusions regarding the sites of the ancient valleys are similar to those arrived at by the writer in the paper quoted, with one important addition.

These conclusions are set out in Figure 3. In this figure the present rivers are shown in order to enable the positions of the old streams to be more readily understood. The actual extent at the present day of the newer basalt occurrences is shown also, as these supply the main evidence for the reconstruction of the old valley systems here attempted. The pre-basaltic valleys are shown by series of arrows; these arrows are firm where the field evidence is definite, but are shown dotted where the evidence is so far incomplete. The system was as follows:—

(i.) In the south-west corner of the area shown in the figure is a portion of the "Ancient Werribee River," flowing east and turning to the south.

(ii.) A little to the north is the small tributary that, since the evidence therefor occurs in the basalt cap of the present Trig Hill, we may call the "Trig Hill Tributary."

(iii.) To the north-east of this a valley came down from the northward, and was basalt-filled up to a point close against the well-known Bald Hill. For the time being we may refer to it as the "Bald Hill Tributary."

(iv.) Further to the east, and coming also from the north, we have the long valley of the Ancient Bullengarook River. This description does not altogether agree with the account of this ancient river as set out by Officer and Hogg (5, p. 67).

(v.) There remains the fact that there existed at that time a large and important stream, the modern Lerderderg, rejuvenated by the Greendale and Gisborne line of uplifts, and, in the extreme north of the area shown in Figure 3, undoubtedly occupying the same valley or gorge that it flows in to-day. The probability is, as pointed out by Dr. Summers, that large fan deltas were deposited by this river below the fault scarp, particularly in the north central part of the area shown. The lower valley of this river must have been in part basalt-filled at the time of the volcanic outpourings. There is no trace of the cross section of such a valley, as far as is known, in any part of the walls of the Basin (see plan of geology, Fig. 2). After a careful consideration of the present heights, and the available geological evidence, the conclusion is reached that the "Bald Hill Tributary," represents portion of the Ancient Lerderderg Valley.

This gives us a fairly complete conception of the pre-newer basalt landscape. The surface was one of low relief, and must have been but little above sea level; the shallow valleys shown were for the most part in the soft level-bedded Tertiary sands, gravels, and mudstones. Low highlands of older and harder rocks existed to the north, above the Greendale-Gisborne fault scarps, but the area with which we are dealing consisted of the fluvatile, etc., deposits laid down under the conditions described in a previous section (Section III.). In the intervening period they must have been preserved by the movements of depression that accompanied their accumulation, but were now sufficiently

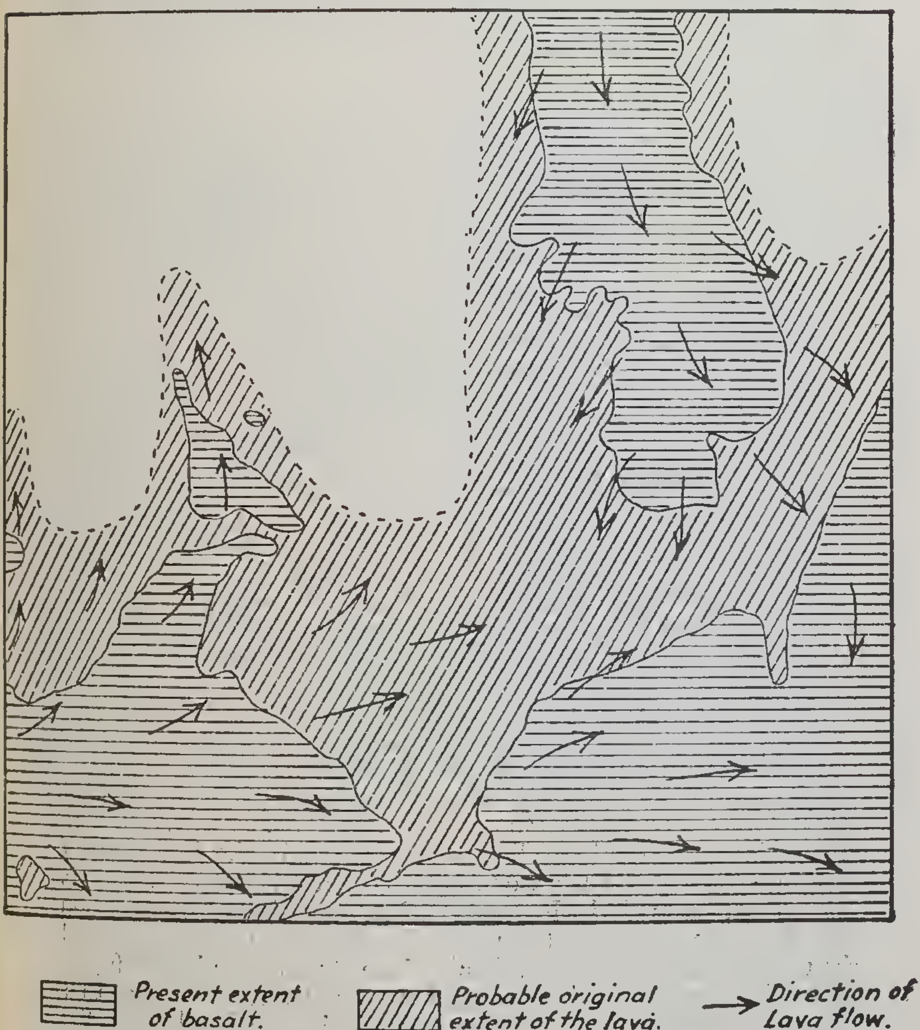

Fig. 4.—Diagram to show the original extent of the newer basalt, and the direction of movement of the lava flows.

uplifted for the formation of the shallow valleys now partly preserved below the newer basalts.

(c) *The Newer Basalt Flows.*—It is thought that the most effective way to outline this account of the gradual development of the physiography would be by means of a series of progressive plans, with descriptions. These plans will serve the twofold purpose of giving definiteness to the descriptions, and of allowing for more exact criticism or confirmation in the light of such other evidence as, now or later, may be brought forward. Ideally, sufficient of these diagrams should be drawn to enable a cinematograph record to be made, but in this case, the number is reduced to six (Figures 4 to 9 inclusive). It is not suggested that any one of these diagrams represents the actual conditions at any set time. They are intended to represent processes rather than products.

We know from the evidence of the levels of the basalt surface, and from the numerous sections exposed, that there were two main flows in this area, one eastward along the Ancient Werribee, and one southward along the Ancient Bullengarook. These in part overflowed the valleys and spread out in thin sheets. There is no evidence that any centres of effusion of lava existed at the heads of the Trig Hill Tributary, or of the basalt filled portion of the Lerderderg Valley. In addition the relationships between the levels at these places and those of the main flow suggest that their basalt-filling came upstream from the south.

Summing up, we have the position shown in Figure 4. This would suggest a special accumulation of lava where the two flows met, in the south-east of the area. It is probable also that the surface junction between these flows gave direction to the first valley of the post-basaltic Werribee over the surface of the lava. We do not know the relations in time between the Bullengarook lava flows and the Werribee lava flows, but it seems safe to assume that they were so close that the actual sequence does not affect the present discussion. There is no evidence regarding the outer limits of the lava in the central portion of the area shown in the figure, but from a consideration of the probable outline of the Lerderderg fan delta, and by analogy with the margins of the basalt sheet in other parts of the State, under somewhat similar conditions, the boundary was drawn as shown.

(d) *The basalt-dammed lake series.*—With the oncoming of the basalt flows (Figure 4) to the stream system shown in Figure 3, one of the immediate results would be the formation of a series of crescentic lakes or swamps. An attempt to show this lake system is made in Figure 5. For convenience in exposition it is here assumed that the newer basalt flows wholly antedated the uplift along the Rowsley Fault. The streams are in this figure given the name of their modern representatives. The lake that was formed by the Korkuperrimul is called Lake Lyall, from the alternative name of that creek; that formed by the Lerderderg and Goodman's Creek is called Lake Lerderderg; and that

formed by the Upper Pyrete is called Lake Coimadai, from the alternative name of that stream. No effort is made to represent the actual extent of the lakes, but it is possible that in an area of low relief, the effect of the basalt banks would be to form lakes more extensive than those shown in the figure. Each of the lakes would develop an overflow outlet, at first somewhat swampy and ill-defined, over the basalt sheet.

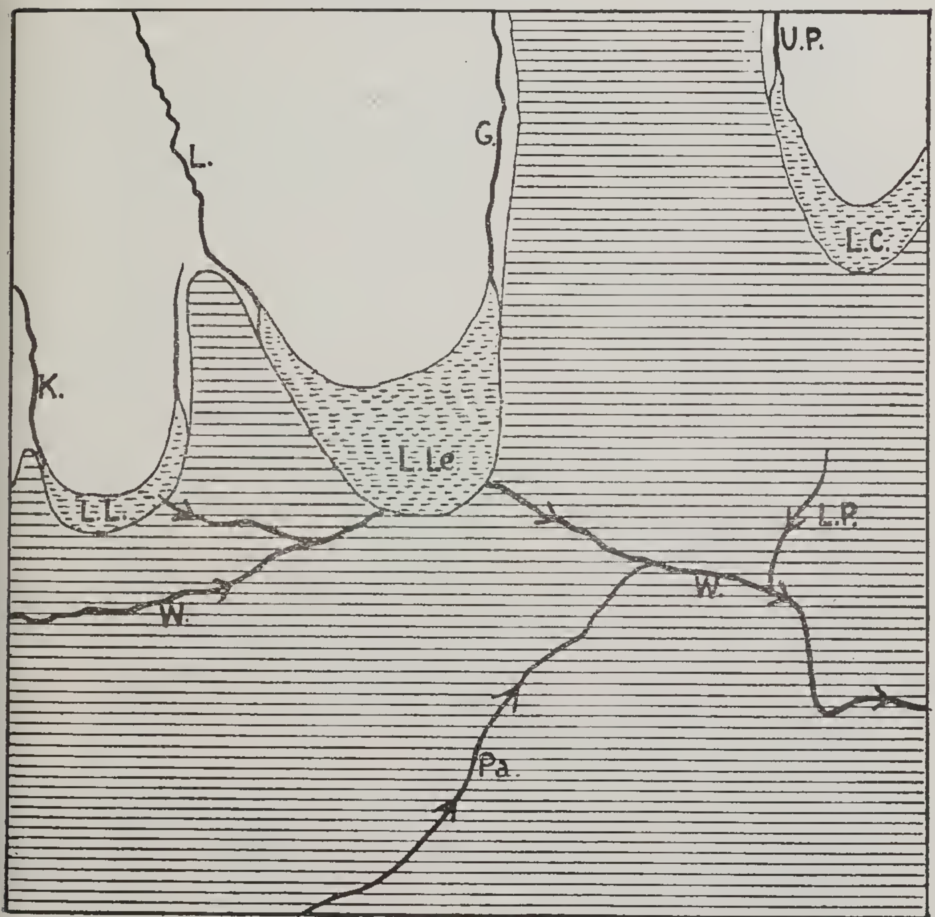

FIG. 5.—Diagram to show the series of lakes formed by the newer-basalt flows. L.L. Lake Lyall; L.Le. Lake Lerderderg; L.C. Lake Coimadai; K. Korkuperrimul; L. Lerderderg; G. Goodman's; U.P. Upper Pyrete; W. Werribee; Pa. Parwan; L.P. Lower Pyrete.

Lake Lyall.—This lake was formed by the Korkuperrimul, between the Trig Hill and Bald Hill basalt tongues. It would probably overflow to the south-east, and would, in common with the other lakes, be subject to fairly rapid silting-up. Doubtless,

"twin streams" were developed on the two sides of the Trig Hill basaltic tongue, and also of the Bald Hill basaltic tongue. The two central streams would, in the soft rocks thereabouts, migrate towards one another to form the present Korkuperrimul Valley.

Lake Lerderderg.—It cannot be determined whether, after the basalt flow, the main Lerderderg River took up its course on the eastern or the western side of the Bald Hill basalt tongue. If on the western side, however, the Rowsley uplift would have diverted it to the eastern side, and it is therefore diagrammed as forming the large lake between the Bald Hill basalt tongue and the Bullengarook basalt tongue. The fact that the Werribee exists where it does to-day, in the western part of this area, in a gorge deeply cut through the basalt, implies the existence of a stream in about that position in the period represented in Figure 5. It is assumed to have flowed into Lake Lerderderg, but whether it did so right from the beginning is immaterial. The Bullengarook basalt tongue gave rise to the twin streams of Goodman's and Pyrete Creeks. Of these, the Goodman flowed into Lake Lerderderg.

Lake Coimadai.—The Upper Pyrete, lateral to the Bullengarook flow, was dammed by the same basalt sheet that gave it birth; this seems clear from the present levels and extent of the basalt sheet (Fig. 2). It appears to the writer that the lake formed by the Upper Pyrete presents features of much greater interest than do the other two lakes, on account of the explanation it may afford of some hitherto puzzling facts.

For many years the limestone deposits of Coimadai have attracted interest on account of their economic value, and their fossil content of mammalian bones. But their existence has never been satisfactorily accounted for, nor their relation to the newer basalts determined. In developing his theory of the formation of these lakes, the writer was struck by the manner in which the accounts of the Coimadai limestones fitted in with the theory of the post-basaltic Coimadai Lake.

That there was a basalt-dammed lake or swamp in this locality cannot be doubted once the facts are brought under notice. In their account of the Coimadai limestones, by Officer and Hogg (5, pp. 63-65), these limestones are described as lacustrine, and as being interbedded with and overlain by a series of sands, gravels, and conglomerates. They contain the remains of extinct marsupials, with undescribed plant relics. Interbedded with them are beds, up to 6 inches thick, of volcanic ash. The age has been suggested as Upper Pliocene to Pleistocene. All these facts fit in with the conditions here outlined from the point of view of physiographic development.

Messrs. Officer and Hogg considered that the lake, in which these limestones and sediments were deposited, was pre-basaltic in age, and that it extended over the whole Bacchus Marsh area—the limestones being deposited in a somwhat sheltered Coimadai

Bay. The writer considers that the present account fits in more closely with the known facts. A consideration of the relative levels suggests that the Coimadai limestones were deposited in a deeper part of the lake, possibly where a tributary valley of the ancient Bullengarook had been left unfilled by the basalt flow. Officer and Hogg's reference (p. 65) to the occurrence of similar limestones within the Bacchus Marsh basin suggests that similar chemical deposits were formed in Lake Lerderderg.[3]

The remaining features of Figure 5 are the young stream courses on the basalt sheet, in the south-eastern part of the area. The Werribee is there assumed to have taken up a course along the line of junction of the two separate basaltic sheets (Fig. 4). The course of the Parwan is assumed to have been somewhat in the position it occupies at present, though it is possible that this stream originally flowed south, to the west of Bald Hill, and was later captured by the headward erosion of a small stream formed as the Basin was deepened (see Commonwealth Military map of the area). A small stream, destined to become the lower Pyrete, is assumed to have arisen where shown on Figure 5; the nature of the basalt flows suggests that Lake Coimadai may have overflowed eastward to the Djerriwarrh Creek, and this lake may have existed long after the other two here mentioned had disappeared.

(e) *The Rowsley Uplift.*—It is assumed, for purposes of clarity, that the Rowsley uplift was, in this area, wholly post-newer basaltic. There is evidence that the assumption is correct. However that may be, the important fact is that there was, about this time, an uplift of that portion of the area west of the Rowsley Fault (shown by a broken line in Figure 6). One effect of this would be the destruction of Lake Lyall, and the commencement of strong headward erosion, from the fault scarp, along the Lerderderg, Korkuperrimul and Werribee, where these streams cross the fault line. A bracket-shaped mark thus [, on these and other streams in these figures, is meant to indicate vigorous headward erosion.

In this figure, the lakes are assumed to have quite disappeared. The stream leaving Lake Lerderderg would soon cut through the basalt sheet, which would be very thin towards its margins. As soon as a definite channel had been cut by these streams, they would be in a condition for doing fairly vigorous work during flood times, having an abundance of grinding tools from the various fan delta gravels, etc.

As the valleys deepened in the basalt sheet itself, the soft underlying Tertiaries (leaf-beds, etc.), would be reached. In these erosion would be very rapid, the basalts would be undercut, and

3.—Since writing the foregoing, the writer has had the opportunity of reading "The Geology of the Coimadai Area" by Arthur L. Coulson, M.Sc. (Proc. Roy. Soc., Vic., Vol. XXXVI. (N.S.), Part II., 1924). Mr. Coulson has investigated in detail the problem of the Coimadai Tertiary limestones, and arrives at conclusions (pp. 171-174) somewhat similar to those set out above, but considers that the lake in which the limestones were laid down was already in existence, in part, at the time of the outpouring of the Bullengarook lava flow.

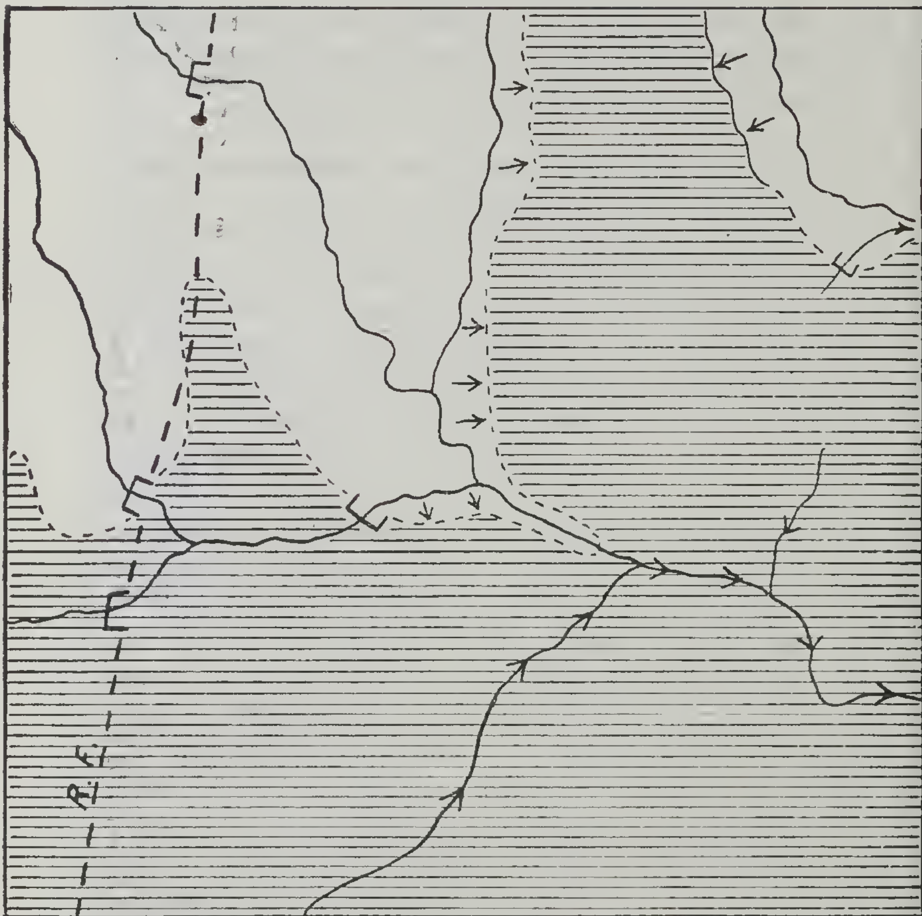

FIG. 6.—Diagram to show the conditions obtaining at the time of the Rowsley Uplift. The fault line is marked R.F. Other marks indicate the nature of the work being done by the rivers, as described in the context.

thus their disintegration and removal hastened. Where the river bed was still in basalt the whole energy of the stream would be concentrated on the downward deepening of its channel. Upstream, where the soft underlying Tertiaries had been reached, there would be much side-swinging, with active attacks on the walls of the embryonic Bacchus Marsh Basin (see arrows, Fig. 6).

In Figure 6, et seq., the chief activities of the streams are indicated by signs, as follows: The sign [indicates headward erosion; the small arrows indicate side-swing erosion and consequent valley widening; the arrowhead *on* a stream indicates downward cutting.

(f) *The final stages of development.*—The subsequent stages of development are set out in Figures 7, 8, and 9, and, with the

various symbols to indicate headward erosion, downward cutting, and valley widening, these figures should convey the writer's idea of the progressive stages of physiographic evolution much more definitely than many pages of verbal description.

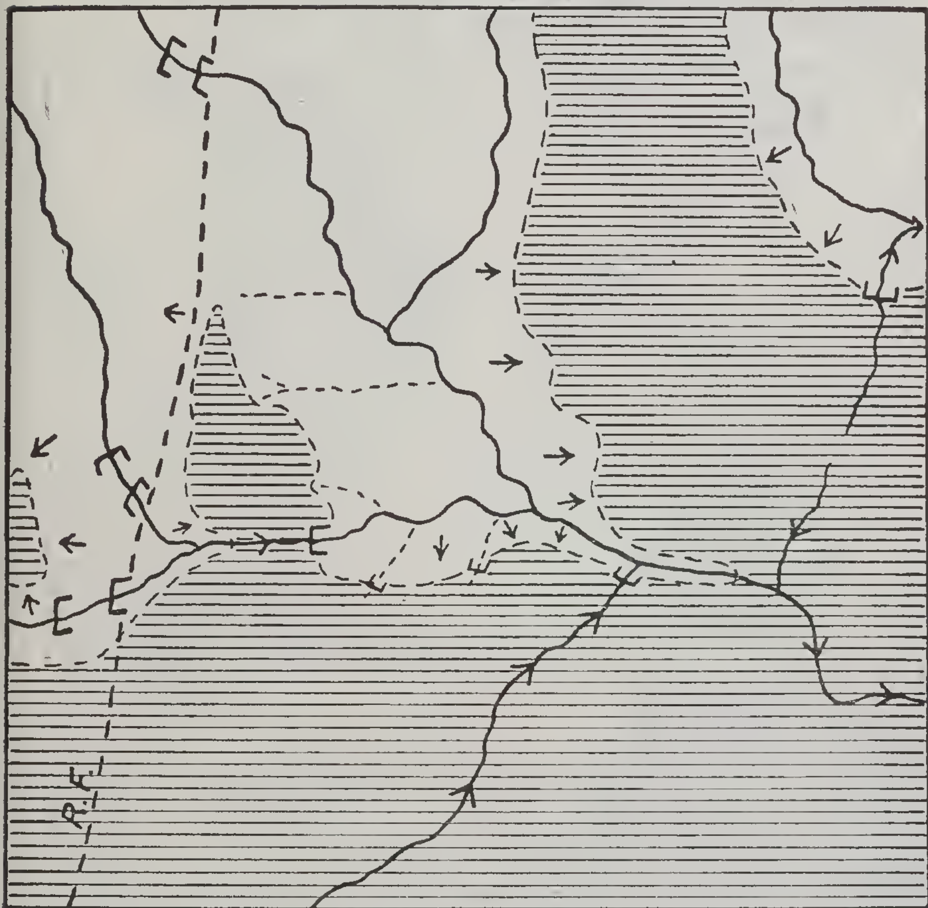

Fig. 7.

Figure 7 represents a further stage. The basalt tongue of the Bald Hill tributary led to the formation of a narrow gorge in the Werribee, where the latter stream crossed the tongue—a gorge that is even to-day distinctly in evidence. The result is a small edition of the Bacchus Marsh flats caused by the swinging of the streams above this bar (see Figure 1). Throughout the paper these flats have been regarded as part of the Bacchus Marsh Basin. The Trig Hill basalt tongue is rapidly disappearing. The Bald Hill tongue is subjected to much less erosive attack, and has not greatly diminished in size; it is in part protected by the accumu-

lation of " fault apron," material. The young Bacchus Marsh Basin is growing, and the basalt sheet has been cut through, in a downstream direction, so that the mouth of the Parwan may now be regarded as within the Basin, that is, it is in the area where it can commence work on the soft Tertiaries. Goodman's and Pyrete Creeks are deepening their valleys, and migrating sidewards away from the basalt tongue that divides them.

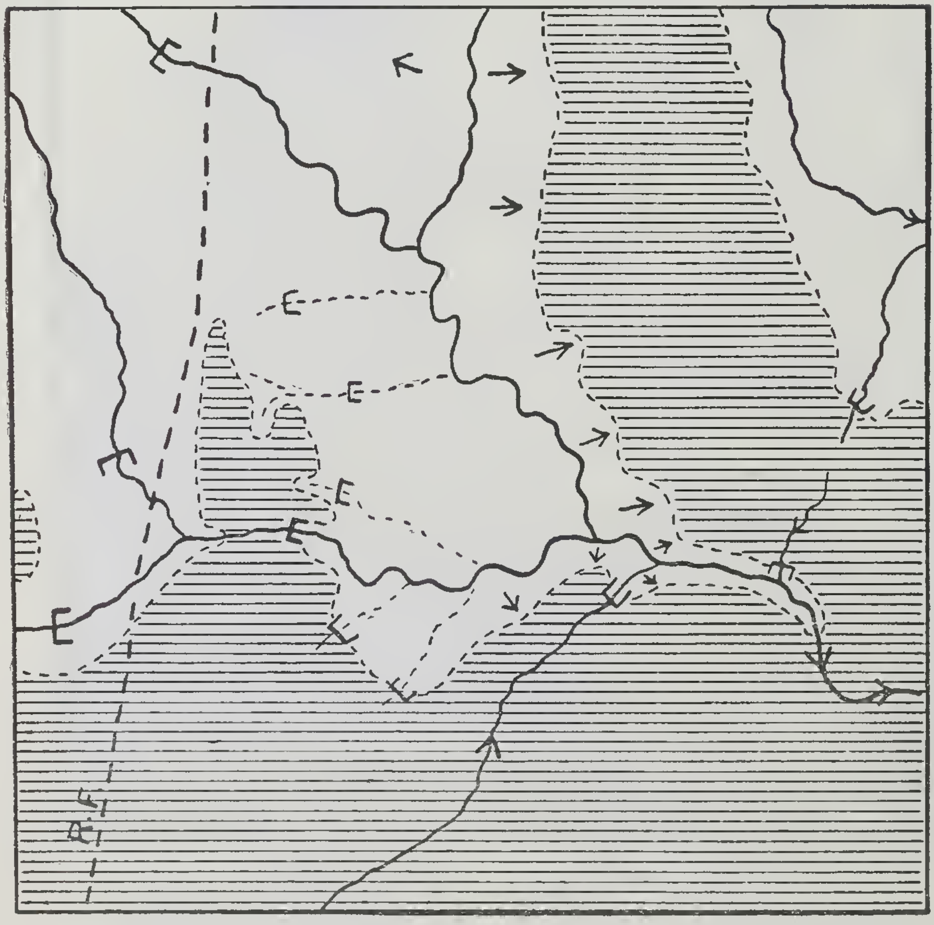

FIG. 8.

The processes shown in the last figure are continued in Figure 8. By downstream cutting the Werribee has now included the Lower Pyrete in the " soft rock " area, and that stream may now commence the headward erosion that will ultimately enable it to capture the Upper Pyrete, which is, at the stage here shown, flowing into the Djerriwarrh Creek. The Parwan is now assisting in extending the area of the Basin by headward erosion, and the

west and southern slopes are pictured as being attacked by small streams. There is some uncertainty regarding the exact present-day margin of the basalt on the west and south of the Basin, owing to the accumulation of scarp face alluvial that occurs there.

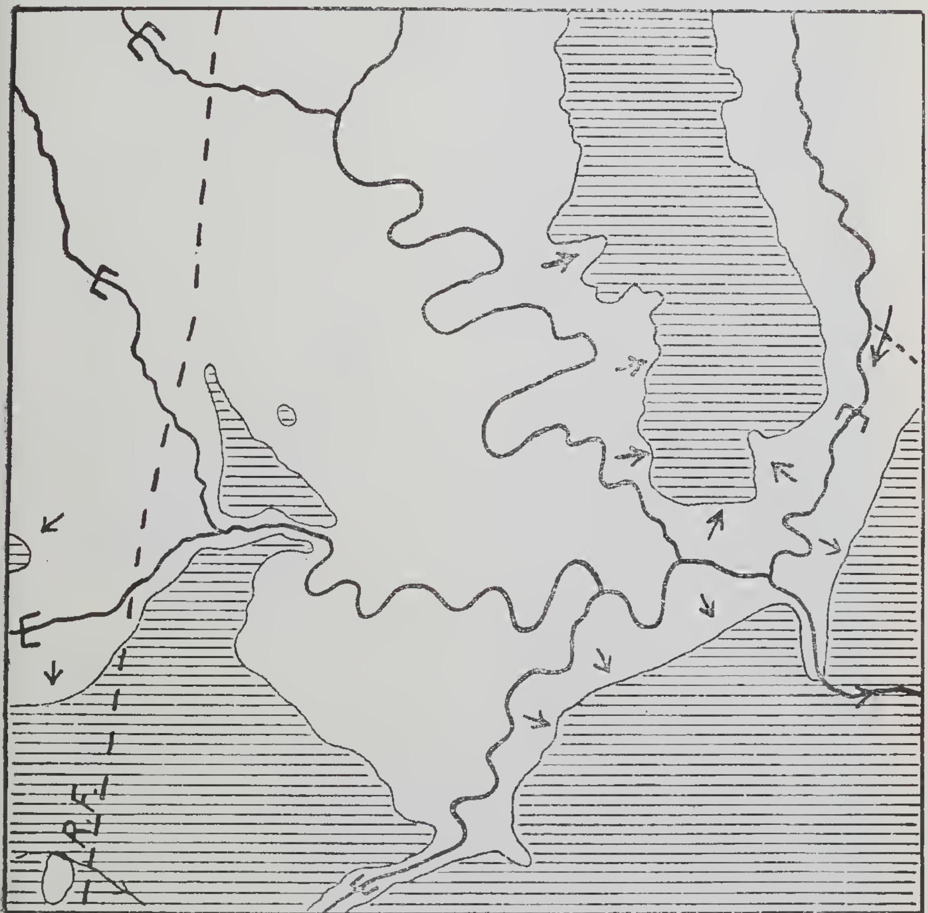

Fig. 9.

In Figure 9, the conditions shown are intended to represent the position just prior to the present day. The margin of the basalt sheet is drawn as it is to-day (compare Fig. 3). The four main streams within the basin are vigorously widening their valley in the soft Tertiaries, the Upper Pyrete has been brought in by capture, and the parent stream (Werribee) has reached the deeper basaltic bar of the ancient Bullengarook Valley. It will be noted that the extension of the Basin is set out as being much greater than at any previous stage; this is intended to indicate the

influence of the Bullengarook basalt tongue—or whatever deeper bar of basalt has been met by the Werribee at the south-eastern limit of the Basin. The "holding-up" of the river in this gorge has led to an enormous amount of upstream sideswinging and valley widening, with the formation of the wide flat-floored valley known to us as the Bacchus Marsh Basin.

Few cases of marked valley-widening above a bar have been recorded for Victorian streams, but there are some well-known examples, notably the Wando and Wando Vale Ponds above the bar of the Hummocks in Western Victoria.

Dr. Summers has mentioned (1, p. 111), as the last stage of geographical evolution here: "Recent deepening of the Werribee Valley below Bacchus Marsh basin, and the consequent dissection of the alluvial flats by the Werribee and Lerderderg Rivers." It is true that the various streams that built up these alluvial flats are now apparently engaged in destroying them. It may be that this is a normal phase of the basin's history. Rivers as a rule build up their bordering alluvial flats during heavy floods, when the silt-laden waters overflow and spread widely over the surrounding country, just as is the case along the Murray River today, or along those of Gippsland rivers that are so busily filling up the Gippsland Lakes. The coming of man, with his systems of drains and snagging of streams, lessens the number and extent of the widespread floods, and causes a concentration of the river action to one defined bed. Two things suggest that this downward cutting of the river beds into the alluvium, with attendant undercutting, etc., has been accentuated since the settlement of the Basin: First, there is the fact that the early settlers gave the locality the name of Bacchus *Marsh,* and secondly, there are swampy areas marked on early maps, where now the streams run in steep-sided channels through tilled fields. When we consider the swinging of streams in soft alluvium, with destruction of roads and other man-made contrivances, there is a strong tendency to think in terms of historical time, rather than of geological time.

If the present economically serious downward-cutting and sideswinging in the alluvium at Bacchus Marsh is to be correlated with the general evidence of recent minor uplift, that is to be found along our coasts, then it must be agreed that such uplift has first led to a deepening of the outlet gorge of the Werribee Basin. It is certainly worthy of note that, apart from a few cases locally explainable, the most marked feature of present-day stream activity throughout the various States appears to be a vigorous downward cutting into alluvial accumulations.

To return to the case of the Bacchus Marsh Basin, it is suggested that its extension is being carried on to-day in much the same manner, and at a somewhat similar rate, as have prevailed during the long period of its development.

Photograph of relief model of the Bacchus Marsh Area.